

## Strength of Moissanite

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**Introduction:** Despite tremendous success of diamond anvil cells in all fields of high-pressure research, there has been a continuous effort to search for new anvil materials that are complementary to diamond but not limited by its cost, availability, and crystal size. In a recent report published in *Science*, Xu and Mao<sup>1</sup> have shown that hexagonal silicon carbide, moissanite, is in this regard an ideal material. It is believed that moissanite anvil cell will open a new window for high-pressure studies that require large sample volumes as well as stable and accurate temperature measurements. To evaluate the applications of moissanite anvils to high pressure-temperature research, one requires the knowledge of the strength of moissanite, which is one of the fundamental properties that measure the resistance to plastic deformation. In particular, the temperature dependence of the yield strength will define limitations on industrial applications of moissanite, if high temperature condition is desired, and on its use as anvil material for high-pressure experiments with external heating.

**Methods and Materials:** In this study, we use the principles outlined by Weidner et al.<sup>2</sup> to obtain information of stress and strength in the powder samples from x-ray diffraction signals. The full-width-half-maximum differential strain for Gaussian distribution at elevated pressure and temperature is calculated by:  $\varepsilon = (1/E)[W_o(E)^2 - W_i(E)^2]^{1/2}$ , where  $E$  is the x-ray photon energy,  $W_o$  the observed peak width at a given experimental condition, and  $W_i$  the instrumental contribution. By multiplying the differential strain by an appropriate aggregate Young's modulus (447 GPa for moissanite), one can convert the strain to stress, which is controlled by the strength of a material.

The strain measurements were performed on the powder moissanite sample using a DIA-type cubic anvil apparatus<sup>3</sup> and a newly developed "T-Cup" high pressure system<sup>4</sup>. An energy-dispersive x-ray method was employed using white radiation from the superconducting wiggler magnet at beamline X17B of the National Synchrotron Light Source and from the bending magnet at beamline 13-BM-D of the Advanced Photon Source. In both experiments, NaCl was used as an internal pressure standard, and temperatures were measured by a W/Re25%-W/Re3% thermocouple.

**Results:** The yield strength of moissanite has been investigated at pressures up to 18.3 GPa and temperatures up to 1200 °C. At room temperature, the moissanite crystal behaves elastically with increasing pressure up to 13.7 GPa. At higher pressures applied, the sample is yielded, and the yield strength of moissanite is determined to be 13.6 GPa. Upon heating at 18.3 GPa, significant stress relaxation is observed at temperatures above 400 °C, and the yield strength of moissanite decreases rapidly from 12.8 GPa at 400 °C to 4.2 GPa at 1200 °C. For comparison, the yield strength of diamond was estimated to be 15 GPa at 1200 °C and 6 GPa at 1550 °C<sup>5</sup>. As expected, moissanite is much weaker than diamond, even though the rate of thermally induced weakening in diamond is substantially greater than that in moissanite.

**Conclusions:** The present results have implications on the development of the next generation of large-volume, high-pressure apparatus, with moissanite as anvil material<sup>1</sup>. The strength of moissanite is highly compromised at temperatures above 400 °C. Above 1000 °C, it becomes even weaker than tungsten carbide at ambient temperature (~ 6 GPa). Such behavior will place severe limitations on the use of moissanite as anvil material when external heating is desired for high pressure and temperature experiments.

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**References:** <sup>1</sup> J. Xu, and H. K. Mao, *Science* 290, 783 (2000). <sup>2</sup> D.J. Weidner, Y. Wang, M.T. Vaughan, M.T., *Geophys. Res. Lett.* 21, 753 (1994). <sup>3</sup> D.J. Weidner et al., In Syono, Y. and Manghnani, M.H. (ed.) *High-Pressure Research: Application to Earth and Planetary Sciences*. pp. 13 (1992). <sup>4</sup> M. T. Vaughan et al., *High Pressure Science and Technology*, 7, 1520 (1998). <sup>5</sup> D.J. Weidner, Y. Wang, M.T. Vaughan, *Science* 266, 419 (1994).